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Edited by: YOUSEF MORADI

With the assistance of Susan Cantan, Edward J. Keall and Rasoul Boroujeni

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Analysis of Two Mortar Samples from the Ruined Site of a Sasanian Palace and Il-Khānid Caravanserai, Bisotun, Iran203
Jonathan Kemp and John Hughes

Analysis of Two Mortar Samples from the Ruined Site of a Sasanian Palace and Il-Khānid Caravanserai, Bisotun, Iran

Jonathan Kemp and John Hughes
University of Melbourne and the University of the West of Scotland

Abstract: Two mortar samples were collected from the ruins of the Sasanian Palace and Il-Khānid Caravanserai at Bisotun to establish whether lime was used in their building and, given the sites' heterogeneity, to make a basic evaluation of their research potential for understanding both production methods and usefulness for dating and correlation with the site's different build phases. Standard polished thin sections at 30 microns were analysed using a polarising transmitted light microscope and an initial characterization of the historic mortars is reported and discussed.

Keywords: lime mortar, Bisotun, petrography, lithology, archaeology, dating.

Introduction

Near the city of Kermanshah in western Iran, lies the historic site of Bisotun. Bisotun has great significance for the history of ancient Iran and for western Asia in general, as it strategically links the Iranian Plateau to Mesopotamia which lies further to the west, and this ancient trade route is still important as a conduit between western parts of Asia with those more central and eastern.

Historically Bisotun exhibits evidence of continuous occupation from prehistoric times down to the present. As well as prehistoric remnants the area features remains from the Median, Achaemenid, Sasanian, and Il-Khānid periods. And of course its highlight is the supremely important bas-relief panel attributed to Darius I, The Great, the fourth king of the Achaemenid era, and made sometime between his coronation in 521 BCE and his death in 486 BCE. Carved into a limestone cliff at the edge of the Zagros Mountains and some 60m above the plain below, this monumental bas-relief and inscriptions describe Dareius' lineage and victories in three different and extinct cuneiform scripts: Old Persian, Elamite, and Babylonian.

In 2007 while working on a condition survey at the nearby Taq-e Bostan, Jonathan Kemp, one of the co-authors of this short article, had the opportunity to study the bas-relief from close up on the ledge from which it was carved. Invited by Dr Kamyar Abdi—then a visiting scholar at the Samuel M. Jordan Center for Persian Studies and Culture, University of California-Irvine and now a lead researcher at the Parseh-Pasargadae Research Foundation and Shiraz University—he and Kemp made the slightly perilous climb up what appeared to be a temporary scaffold on a late afternoon with the sun dipping over the mountains beyond. After discussing some of the conservation issues affecting the bas-relief, it was when looking back across the north-western section of this area, to the beginning of the great plateau that stretches from the foot of the Parthian slope, that Kemp noticed how many historic ruins litter the landscape. In particular, the unfinished remains of the Sasanian palace attributed to Khosrow II and overlaid by remnants from the Il-Khānid Mosque and Caravanserai were noticeable in the foreground (Fig. 1). As the plateau sweeps away, to the viewer's right is the restored Shah Abbasi

Fig. 1 General view of the ruins of the Sasanian Palace and Il-Khānid Caravanserai at Bisotun.

Caravanserai, now a hotel, and further still, but impossible to see from the bas-relief, the incomplete and abandoned Farhād-Tarāsh panel.

It is from the outlier precinct of the mix of Sassanid Palace and Il-Khānid historic remains periodically excavated over the last forty years by the esteemed archaeologist celebrated in this festschrift, Mr. Medhi Rahbar[1] - that Kemp—serendipitously as it turns out in terms of presenting this short article—collected some extant mortar samples for later petrographic analysis from what were assumed to be ruined Sasanian stone walls.

Rationale

This random sampling was executed with a view to not only establish whether lime was used at Bisotun in the Sasanian period but also, given the sites' heterogeneity, to understand whether there would be anything identifiable that might, in the future, help correlate samples to different historic build phases.

However, where it is sometimes possible to understand phases by observing and analysing different mortars in the same group of buildings, attributing a date to a mortar sample is very difficult, expensive and complicated. On the other hand, if a mortar exhibits any organic content this may make it suitable for radiocarbon dating although with the caveat that relying on this alone can yield dates older than the actual mortar.

Briefly, atmospheric carbon dioxide (CO_2) is fixed in the carbonate formed during the hardening of lime mortar at the time of application and, as such, this in principle makes it suitable for radio carbon dating. To produce lime for the mortar, limestone is heated to at least 900°C to liberate CO_2 and produce quicklime (calcium oxide, CaO), which is then slaked with water to form a calcium hydroxide ($CaOH_2$) paste. This paste is then mixed with aggregate, normally sand, and water to form a lime mortar.

For the mortar to set hard the $Ca(OH)_2$ binder reacts with atmospheric CO_2 to eventually form calcium carbonate ($CaCO_3$) in the hardened mortar. Pozzolanic material such as crushed brick might be added to speed up the set. In theory it might be possible to measure the time elapsed from the time of hardening although in practice it is very uncertain. For example, the mortar may contain

1. Assumed to be detailed in the internal ICHTO excavation reports: B-Re/re-0002, B-Re/re-0009, B-Re/re-0010, B-Re/re-0011, B-Re/re-0020 and B-Re/re-0028 – see http://bisotun.ichto.ir/Portals/bisotun/Asnad/Liste%20File%20Gozareshat.pdf?ver=1393-09-20-203102-290 (in Persian) (accessed 21 December 2018).

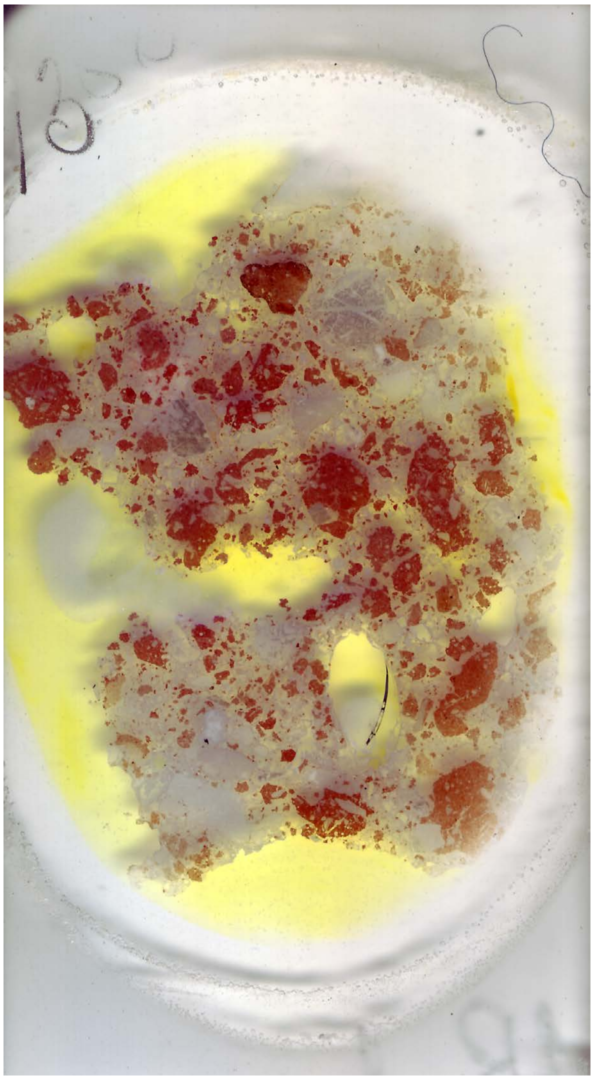

Fig. 2 Desktop scan of thin section of specimen IR1. Binder supported with large sub-rounded red/brown ceramic fragments, possibly brick. Large paler grey grains are limestone fragments. Yellow areas are yellow-dyed epoxy resin to consolidate the sample and fill any porosity. Narrow dimension of slide is 2.5 cm.

old limestone, either as remains from incomplete conversion into CaO in the burning process or from carbonate inclusions in the aggregate, yielding results that can suggest ages incompatible with other extant evidence. Alternatively, delayed hardening in any thick mortar or later recrystallization of the carbonate can incorporate 'younger' CO_2 which can suggest dates that might otherwise seem too recent.

Analysis

Polished, standard thickness (30 um) thin sections of two small specimens of mortar were prepared and investigated using transmitted polarising light. The results are as follows.

In the first sample considered, IR1 (Fig. 2), the mortar is binder supported, assumed (but not proven) to be a lime-based binder. The temper or aggregate is dominated by coarse to very coarse brick (certainly some form of ferruginous ceramic if not brick) fragments, up to 4 mm in size, predominantly 1-2 mm in largest dimension, with medium sphericity and sub-angular to sub-rounded in texture.

The aggregate also comprises a less abundant coarse grained, sub rounded carbonate lithology, estimated at around 30% of the aggregate. This is a limestone; a matrix supported biomicrite with sparse sparry recrystallized shell fragments and calcite veining (though the precise polymorph of carbonate is uncertain). There are also equant (round) sparry calcite fragments (coarser crystals, though still in the low μs range) that is possibly a different lithology.

Several fragments of the limestone have altered edges, merging into a textures similar to the general binder groundmass. This implies that this lithology was likely the source raw material for binder production to manufacture the mortar and that the mortar is bound by lime. These fragments are remnants of un-calcined materials that now serve as aggregate.

The brick fragments have a brown, presumably ferruginous groundmass, with sub-angular to rounded larger carbonate temper inclusions (mms across) similar in lithology to the lager limestone fragments that may be source material for the binder. Brick fragments have binder-poor haloes surrounding them; an interfacial zone with lime binder depletion.

There are many smaller (<1 mm) brown micritic, rounded lime inclusions—fragments of binder that have been hydrated, but not fully mixed with the mortar binder paste, so they retain textural continuity in the mortar. There are also many examples of skeletal pseudomorph outlines of inclusions, with denser exterior layers, but interiors of recrystallised carbonates, most often as a sparry isopachus layer. There is much evidence like this for carbonate dissolution and increased secondary porosity, with selected recrystallisation around some pores and in cracks. The binder in many areas appears depleted and with increased porosity.

The second specimen, IR2 (Fig. 3) presents differently from IR1. It is a binder supported mortar with a poorly sorted aggregate/temper fraction, that comprises mainly large (~5 mm) limestone fragments with a similar petrography to those seen in IR1 (micritic to very fine grained recrystallised spar). There are also some large brick/ceramic fragments and numerous smaller <1 mm brick fragments throughout.

In contrast to IR1 the aggregate also includes a relatively abundant coarse silicate lithology. These are low porosity polycrystalline quartz grains with undulose extinction, poorly sorted grain size and irregular, sutured grain boundaries, tentatively attributed to a quartzite (quartz rich low-medium grade metamorphic rock). Commonly there are single crystals of an alkali feldspar, that appears calcified (a reaction to a carbonate mineral) from their edges in continuity with the crystal twinning and cleavage orientations. This appears to be a reaction that has taken place in the mortars since manufacture.

Several areas contain a near opaque dark binder-like material, with silicate inclusions, that possibly comprises some form of slag. This is a tentative identification, however the materials certainly are probably related in genesis to lime and lime inclusions. The mortar also contains many lime inclusions, with micritic textures, and common shrinkage cracks. Several of the limestone fragments have altered margins suggesting they are un-calcined remnants from kiln processing (i.e. this is the limestone used to produce the lime binder).

There is also a lime inclusion which appears to contain a possible fragment of charcoal, suggesting that wood was used as the fuel for lime production.

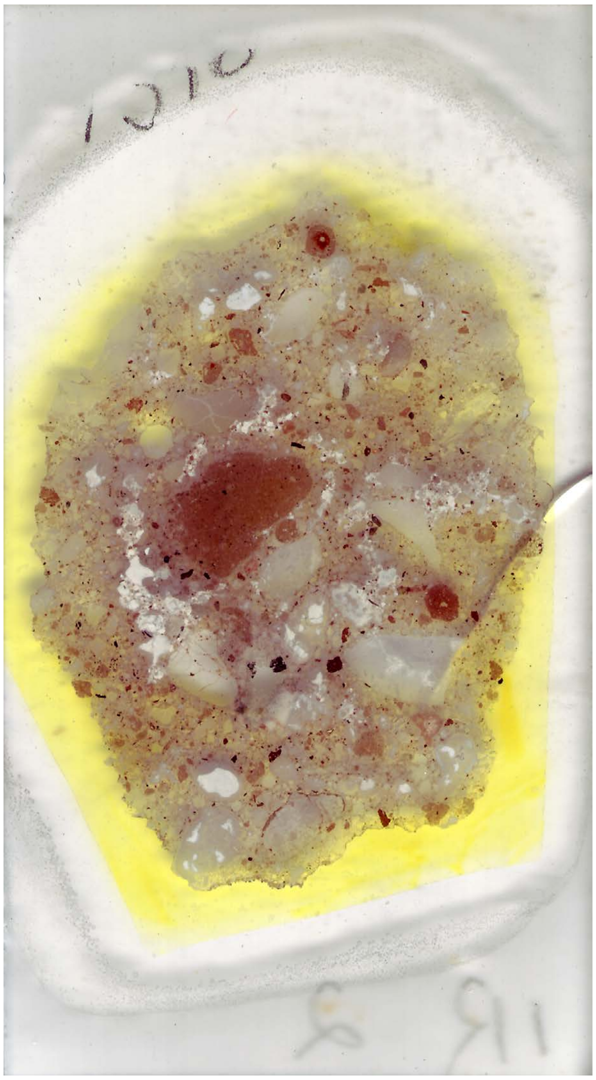

Fig. 3 Desktop scan of specimen IR2. Binder supported. Large sub-rounded red/brown brick fragments at centre of image. Large pale-grey grains are limestone fragments. Bright, near white areas (e.g. to lower right of large brick fragment), are in transmitted light dark brown coloured, opaque, dense areas. Yellow areas are yellow-dyed epoxy resin to fill porosity. Narrow dimension of slide is 2.5 cm.

Discussion

The results from petrographic analysis of the two samples indicate the likely problems faced by any attempt at radiocarbon dating of the $CaCO_3$ they contain as together they exhibit un-burnt source limestone, secondary calcite fragments and recrystallized carbonates, all of which, as indicated above can cause 'noise' around dating accuracy. However, IR2 also exhibits what appears to be a fragment of charcoal which also suggests bulk sampling might yield sufficient organic elements useful for more accurate dating.

Conclusion

The research potential of these ad-hoc samples suggests that any more systematic and rigorous program of sampling and analysis might prove useful in correlating the different phases of building on the site. Without any foreknowledge of whether this is indeed what any esteemed colleagues elsewhere may have already have been doing at Bisotun, we offer our somewhat disconnected insight in the spirit of camaraderie we hope befits the occasion of honouring Mr Rahbar for all his important work on the history and culture of Iran.

آفرین نامه

مقاله‌های باستان‌شناسی در نکوداشت استاد مهدی رهبر

به‌کوشش: یوسف مرادی

با همکاری سوزان کنتن، ادوارد جان کیل و رسول بروجنی